California Transportations

Information on the Tower Legs and the Shear Links

for

San Francisco-Oakland Bay Bridge East Spans Seismic Safety Project

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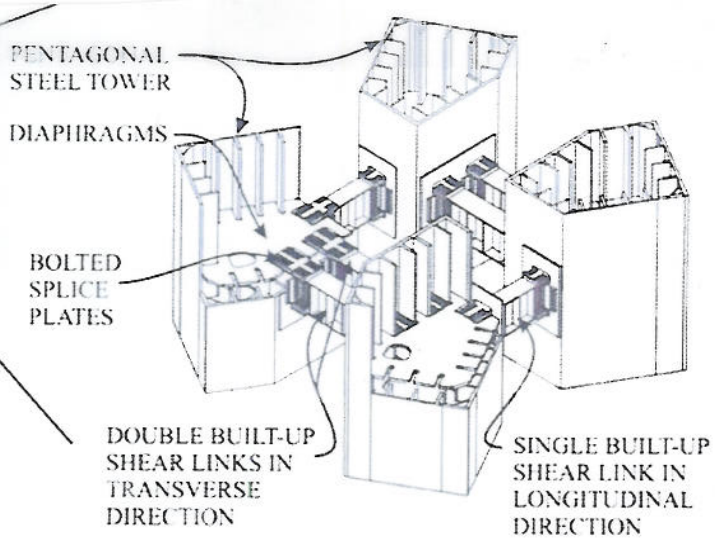
Overview

This informational handout is by no means complete in regard to the fabrication and installation of the test set up for shear links. The Department is providing this information and pictures to assist bidders in planning the fabrication and erection of San Francisco-Oakland Bay Bridge (SFOBB).

General Arrangement

The tower of the suspension span portion of the SFOBB consists of four shafts that are pentagonal in cross-section and interconnected by shear links. The shear links are in 20 locations distributed throughout the height of the tower. Due to the different response characteristics in the principal horizontal directions of the bridge, a single shear link connects adjacent shafts in the longitudinal direction while two parallel shear links connect adjacent shafts in the transverse direction. Sections of two tower shafts were fabricated at half-scale to replicate the conditions of both of these tower-to-shear link scenarios in the laboratory.

Rendering of the new
San Francisco-Oakland Bay Bridge
Self-Anchored Suspension Span
(by T.Y. Lin International)

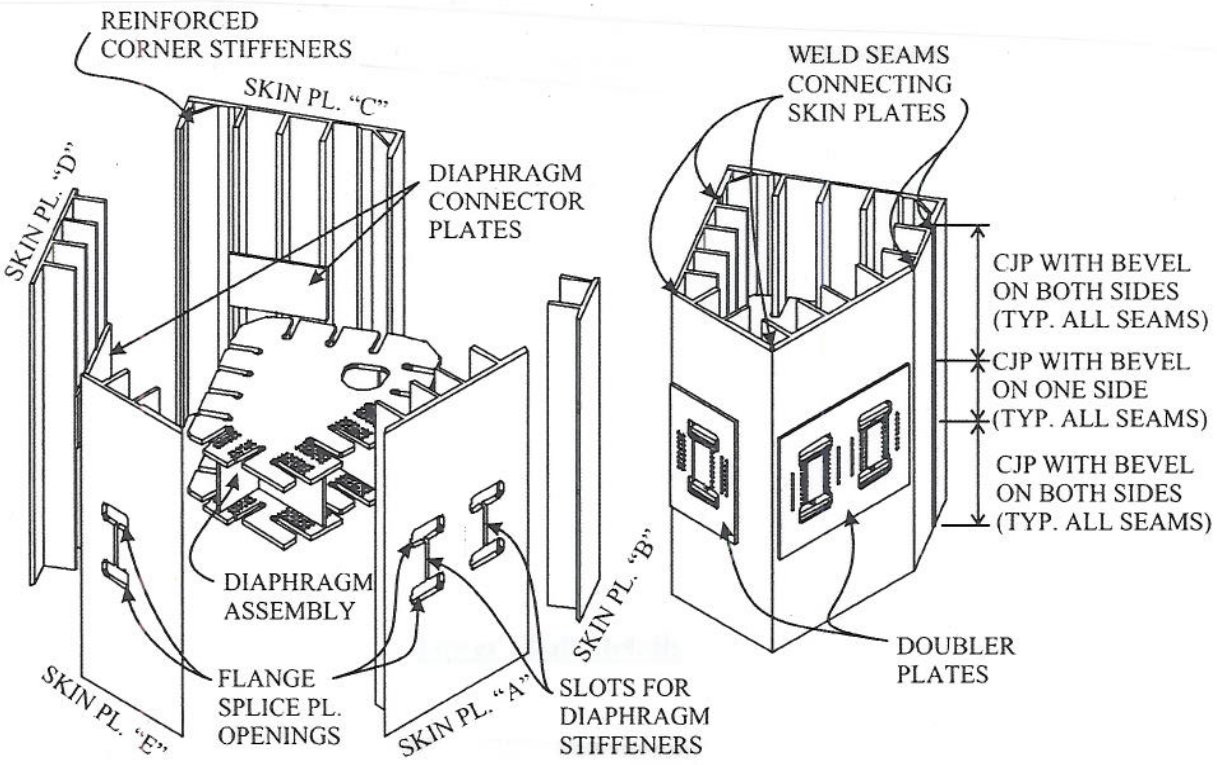


Rendering of SFOBB Tower Shaft Assembly

Tower Shaft Description and Fabrication

T.Y. LIN International in San Francisco designed half scale tower components for testing at the University of Nevada Reno in 2001. The testing included two tower shafts, link beams, and all connecting plates. Christie Constructors Inc. of Richmond, CA fabricated the components. Quality control for the fabrication and welding was conducted by Testing Engineers Inc. of Oakland, CA and quality assurance by Caltrans representatives from Law Crandall of San Diego, CA. The test samples were destroyed after the testing was completed.

The half-scale SFOBB shaft sections were 2.5 m (8.20 Ft.) long and were representative of the tower at Elevation 89 meters (292 ft). The skin plate thicknesses varied along the perimeter between 30 mm (1.18 in) to 50 mm (1.97 in) and were reinforced by 35 mm (1.38 in) thick stiffeners. Doubler plates were welded to the skin plates at the location of shear link connections. Horizontal internal shaft diaphragms were welded in place with the shear link flanges to provide load transfer from the link to the shafts.



a) Tower Shaft Components **b) Assembled Shaft Section**

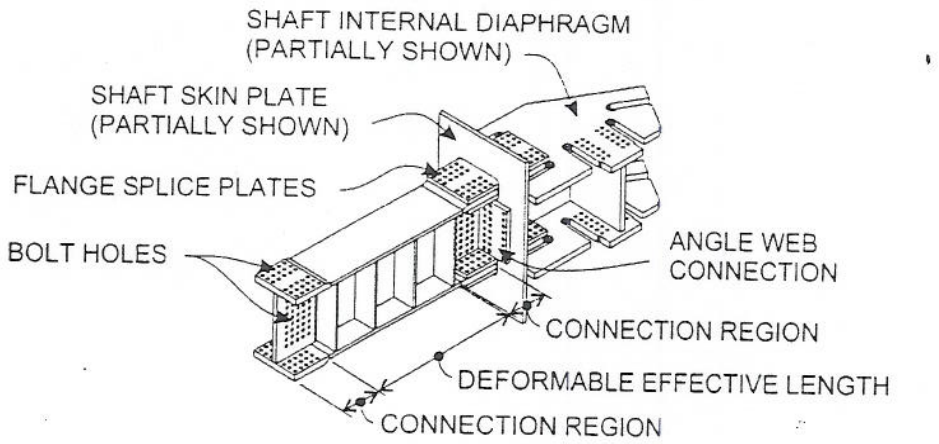
Tower Shaft Details

The design provided for challenging fabrication with special attention required to be paid to the welding sequence. Each shaft was fabricated as follows:

1. The diaphragm assembly, which consisted of top and bottom pre-drilled diaphragm plates and diaphragm stiffener plates, was welded together.
2. Stiffeners were welded to individual tower skin plates A through E
3. Slot openings were made in skin plates A and E between the splice plate openings to allow access for welding the stiffener of the diaphragm assembly.
4. Diaphragm connector plates were welded to stiffeners of skin plates C and D.
5. The diaphragm assembly was welded to the diaphragm connector plate of Skin plate D.
6. The remaining reinforced skin plates were tack welded around the diaphragm in the order E, A, B and C.
7. The seams connecting the skin plates were welded using double bevel full penetration welds. Where access was restricted to only one side, i.e. at the locations of the diaphragms, a single bevel full penetration weld had to be made.
8. The diaphragm was welded around the perimeter to the skin plates and stiffeners from inside the shaft.
9. The diaphragm stiffener was welded using the slots in skin plates A and E.
10. Doubler plates were fillet welded and bolt holes drilled in the location of the shear link connections.

Typical Shear Link Layout

To allow for the shear link bolted connections, each shear link consisted of three distinct regions: the deformable length in the middle and two connection zones at the ends. The link connection zone was designed to remain elastic by incorporating higher strength or thicker plates to compensate for the reduction in net area from the bolt holes. Each link was bolted to the tower shafts using splice plates for the flanges and angles for the webs. The splice plates extended inside the shafts and bolted to the diaphragm, while the angles connected the web to the outside skin plate.



Typical Shear Link Layout

Steel and Bolt Grades

The shaft diaphragms, splice plates and connection angles were made from ASTM A709 grade 485 MPa (70 ksi) high performance weathering steel. The remainder of the test setup was made from ASTM A709 grade 345 MPa (50 ksi) steel. All bolts connecting the link to the tower shafts were M16 – A490 grade with threads excluded from the shear planes. The M16 bolts were tightened by a torque wrench that was calibrated to the required bolt pretension force of 107 kN (25 kip) as specified in the Manual of Steel Construction (AISC 2001). The calibration of the wrench was conducted by tightening a bolt between two representative splice plates and measuring the force using a load cell.

Typical Shear Link Installation Sequence

Each shear link connection zone was drilled prior to each experiment in order to ensure proper fit. Due to the fixed locations of the tower legs, the installation process involved temporarily moving some of the flange splice plates out of the way. The following sequence of steps was used:

1. Bolts were pre-installed in the skin plate of the tower shafts.
2. Both full-width flange splice plates and two of the half-width flange splice plates (both on the same side of the shear link web) were bolted to the diaphragm in their final positions.
3. One web angle was bolted to the skin plate on the same side as the two half-width flange splice plates.
4. The two half-width flange splice plates on the other side were installed and pushed inside the tower, flush with the skin plate.
5. The shear link was slid into place.

6. The half-width flange splice plates that were inside the tower were pulled out into position and bolted to the diaphragm.

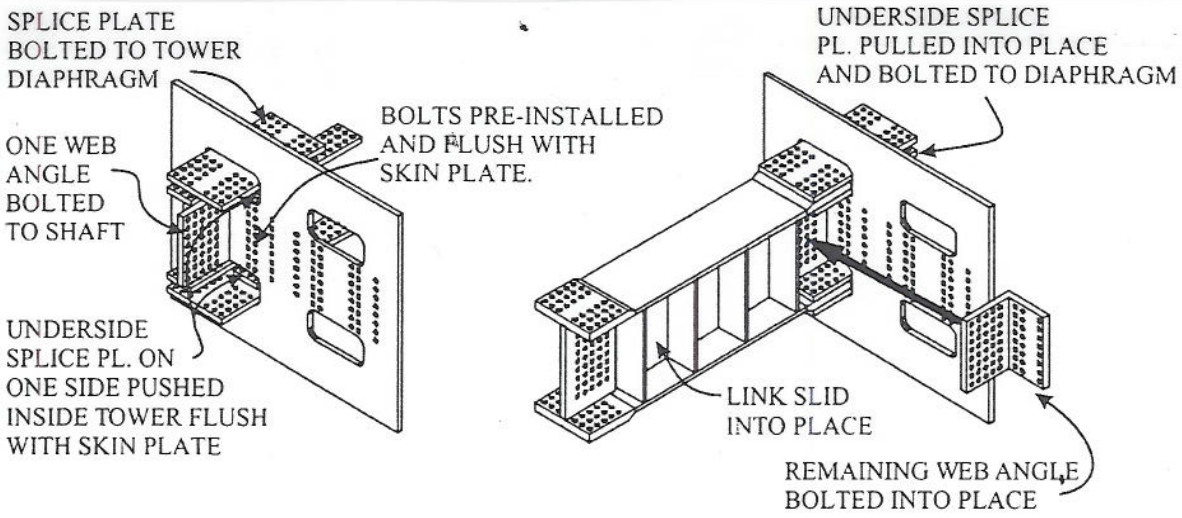
7. The remaining web angle was bolted to the skin plate.

8. The shear link was clamped and holes marked with a portable magnetic drill using the flange splice plates and web angles as templates.

9. The shear link was removed and holes drilled according to the marked locations.

10. The shear link was installed by repeating steps 4 through 7.

11. All bolts were installed and tensioned.



a) Connection Preparation **b) Link, Splice Plate and Web Angle Installation**

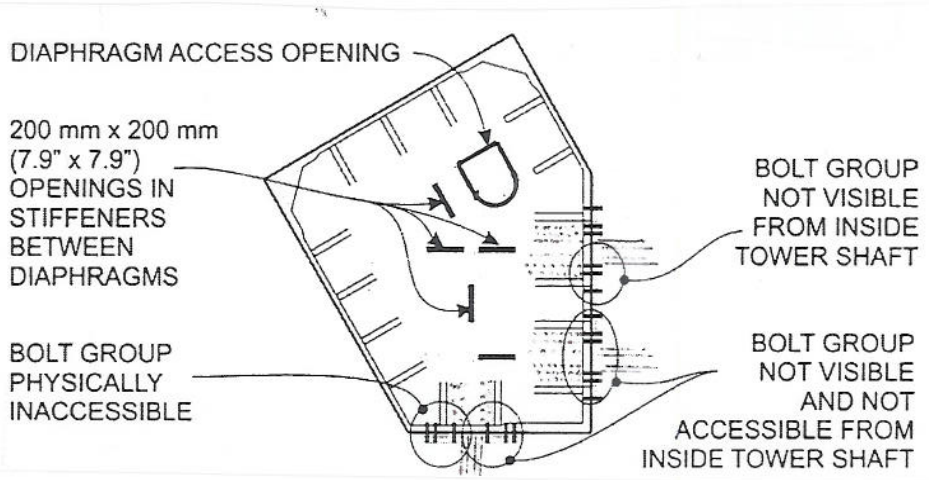
Shear Link Installations

INSTALLATION ISSUES

A number of issues were encountered during installation of the shear links and related to the tower shaft designs. These were mainly related to the lack of accessibility or space in parts of the tower shafts.

Access to Skin Plate Bolts

The majority of the bolt holes in the skin plates were not accessible from inside the tower shaft because the holes were located between the top & bottom diaphragm plates and were often hidden behind numerous stiffeners. As a result, some bolts had to be placed inside the tower through the holes for the shear link flange splice plates. They were then pulled into the bolt holes using fishing wire that was attached to 3 mm (0.12 in) machine screws that were drilled and tapped at the threaded end of each bolt. This issue might be less of a problem when scaled to full-size since the holes in the tower skin for the flange splice plates would be larger and give more access.



Tower Shaft Section Showing Locations of Inaccessible Bolt Areas

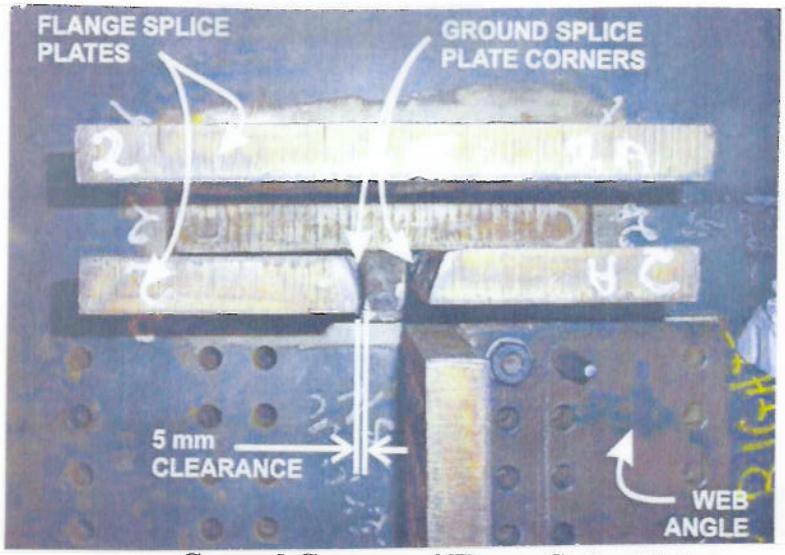
Field Welding of Web Stiffeners

Variation from the general procedure of shear link installation was needed for the shear link in the longitudinal test setup. In this case, the half-width flange splice could not be pushed inside the tower shaft due to interference with the diaphragm stiffeners. The

splice plates also could not be installed after the link was in place due to interference with the shear link web stiffeners. As a result, shear link stiffeners had to be removed on one side so that the shear link could be drilled and bolted into place. The stiffeners were then field welded back after the bolts were tensioned.

Flange Splice Plate Clearance

Design details of the half-width flange splice plates for the transverse assembly indicated 5 mm (0.2 in) clearance between the splice plates and the stiffener inside the tower connecting the web diaphragms. However, the presence of welds at that location exceeded this tolerance and prevented installation of the splice plates. The inside corners of the splice plates were ground to provide adequate clearance for installation.

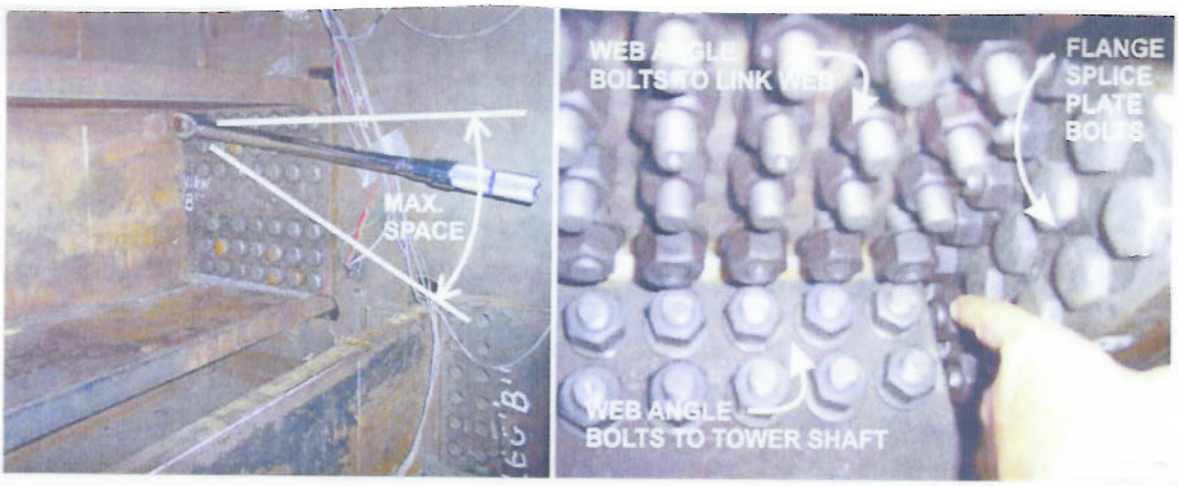


Ground Corners of Flange Splice Plates

Bolt Accessibility

Tightening of bolts inside the tower shafts as well as in the shear link connection regions was difficult for certain bolt groups. Inside the tower, bolts were located close to the skin plate and next to the skin plate stiffeners. While the socket was able to reach all of the

bolts, the process of turning the wrench during tensioning was restricted to a few degree turns at a time. The wrench either hit the stiffener next to the bolt or the stiffeners on other sides of the tower shafts. A shorter wrench would not provide sufficient lever arm for applying the required torque. Also, flange bolts closest to the skin plate within the link connection zone were not accessible. Rigs and jamming devices had to be used to hold the nut during the bolt tightening process. As a result, bolt installation and tensioning became a laborious and time-consuming process.



(a) Wrench Access Inside Tower (b) Bolt Access at Connection Joint

Bolt Accessibility Issues

Disclaimer: The information presented here in was gathered informally in late 2005. The handout presents information about the methods used the fabrication and assembly of test specimens similar to components of the new Bay Bridge. It is not represented to be the only or even the preferable way, to construct the towers of the Bay Bridge. The contractor is responsible for the means and methods used for such work during performance of the contract.

SFOBB SAS

Photo simulation of the Replacement Alternative N-6 as viewed from Yerba Buena Island

SFOBB SAS tower section

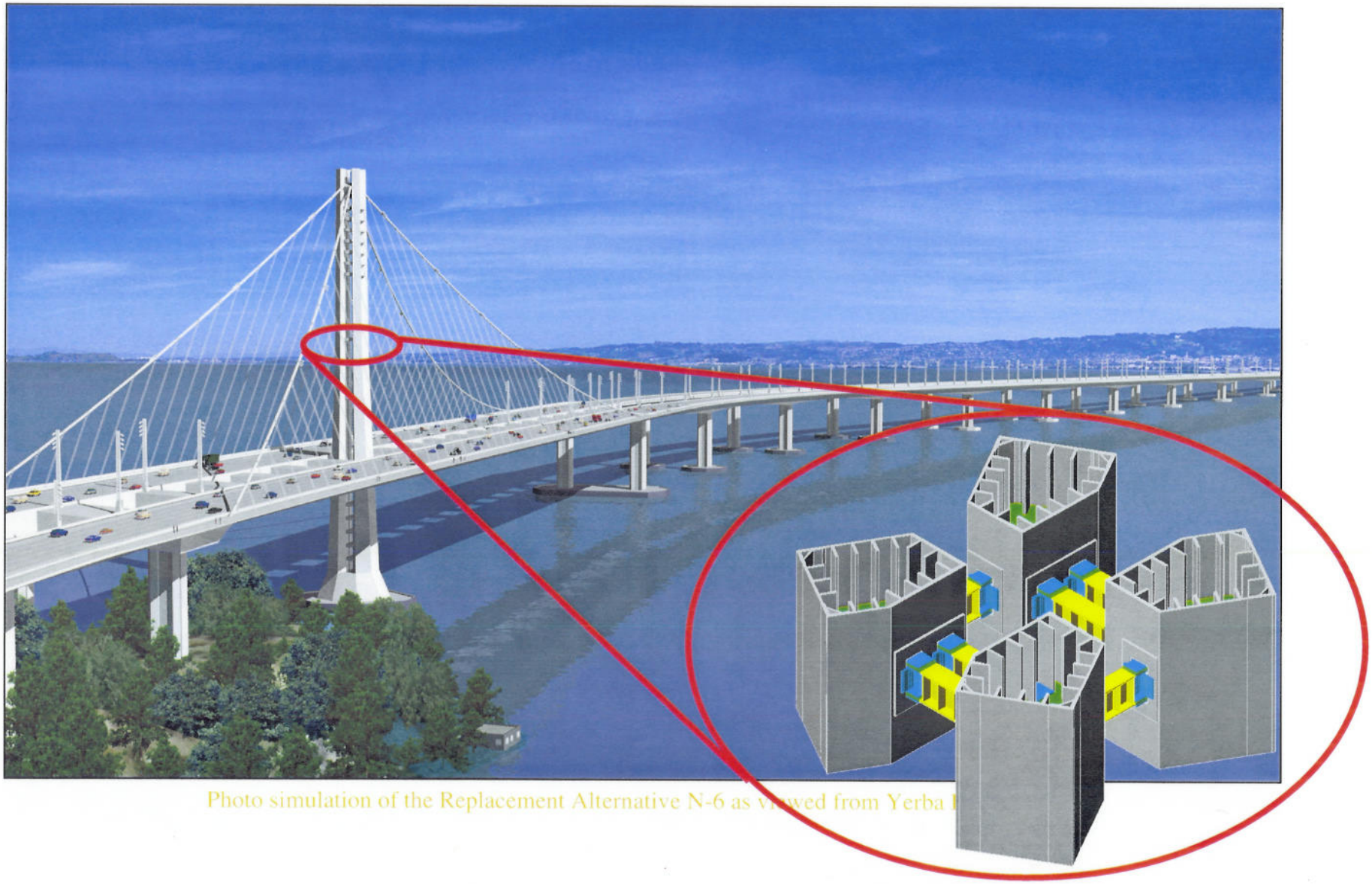
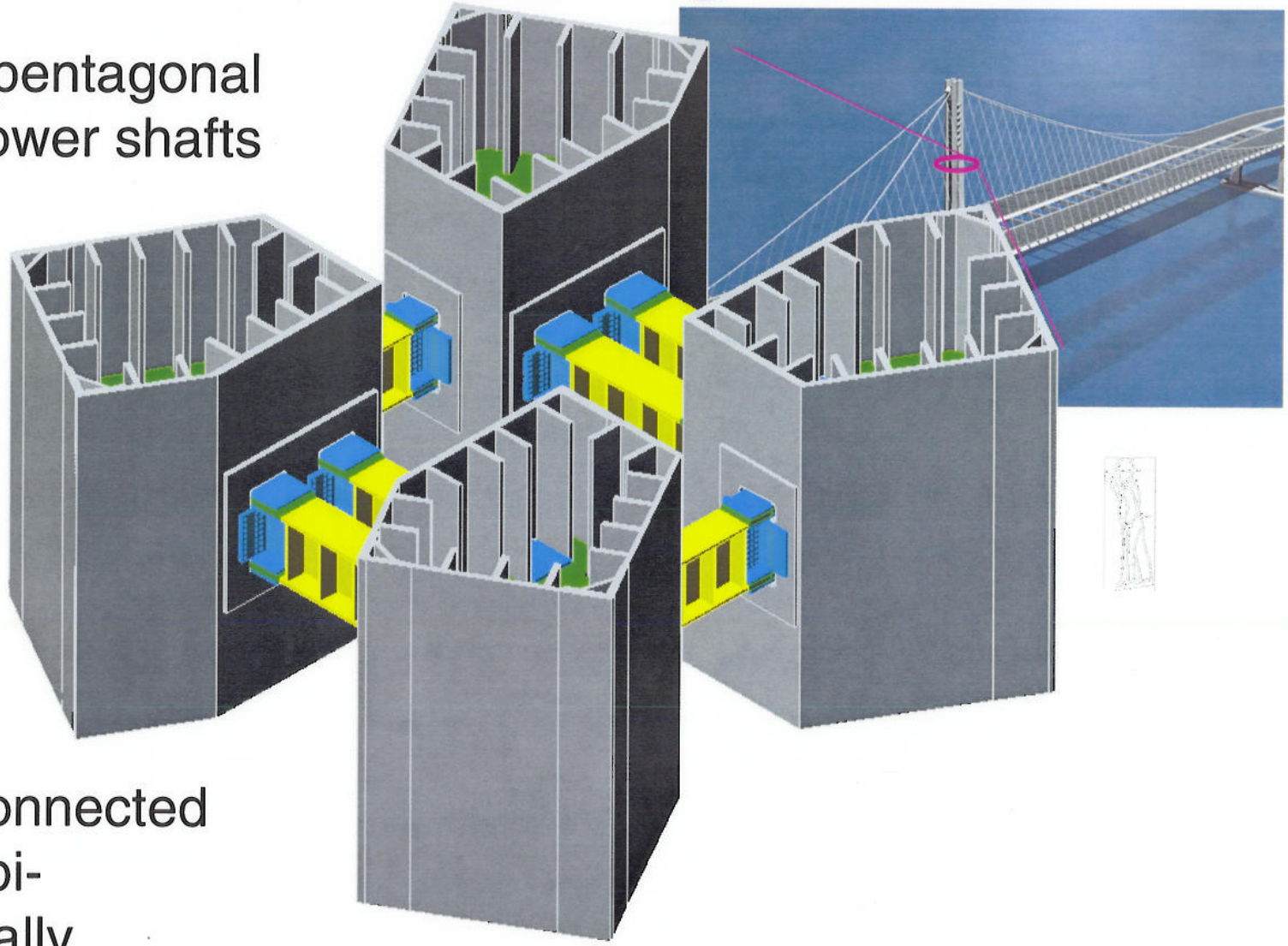


Photo simulation of the Replacement Alternative N-6 as viewed from Yerba

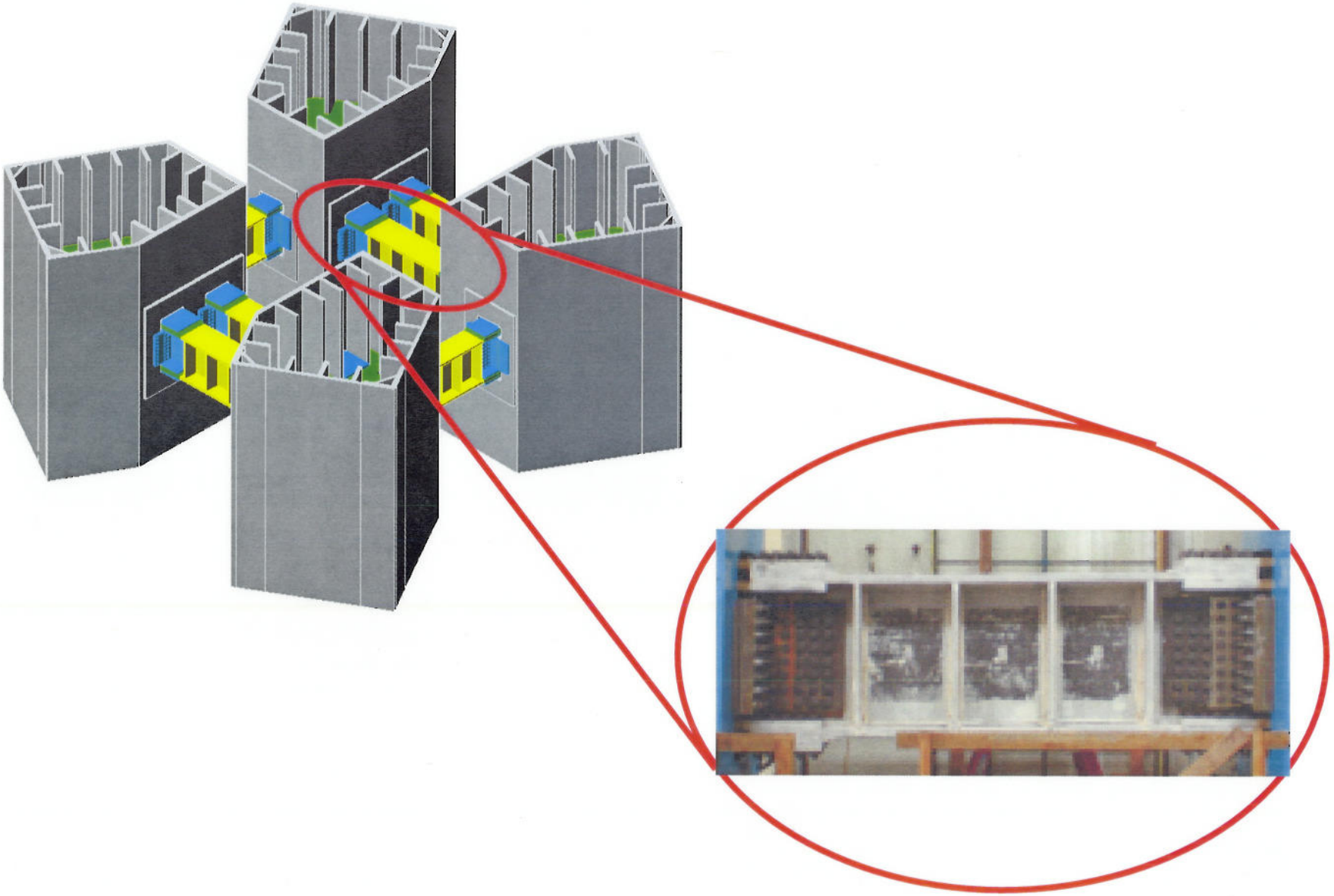
Four Shafts in Single Tower

Four pentagonal steel tower shafts

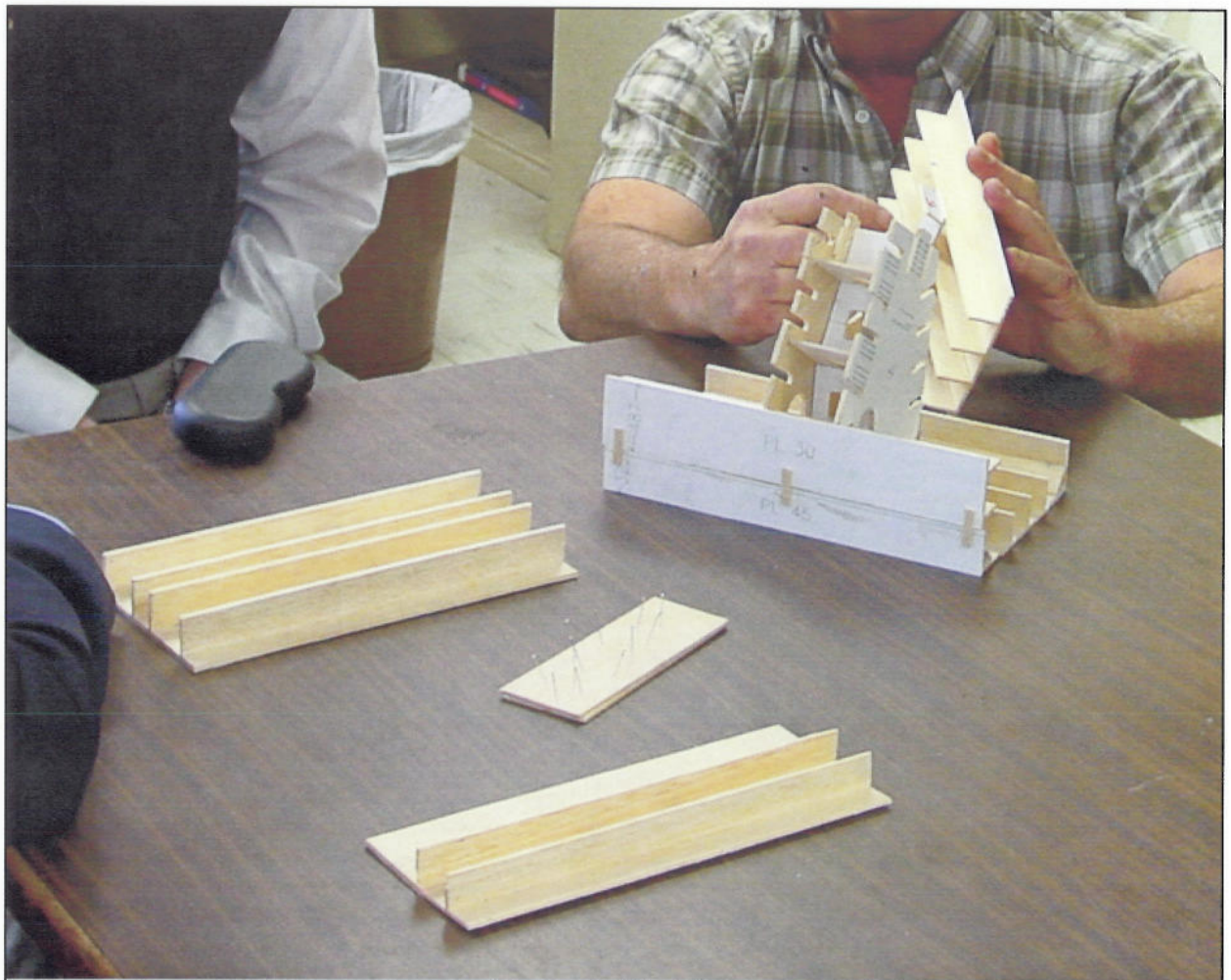


Shafts connected by links bi-directionally

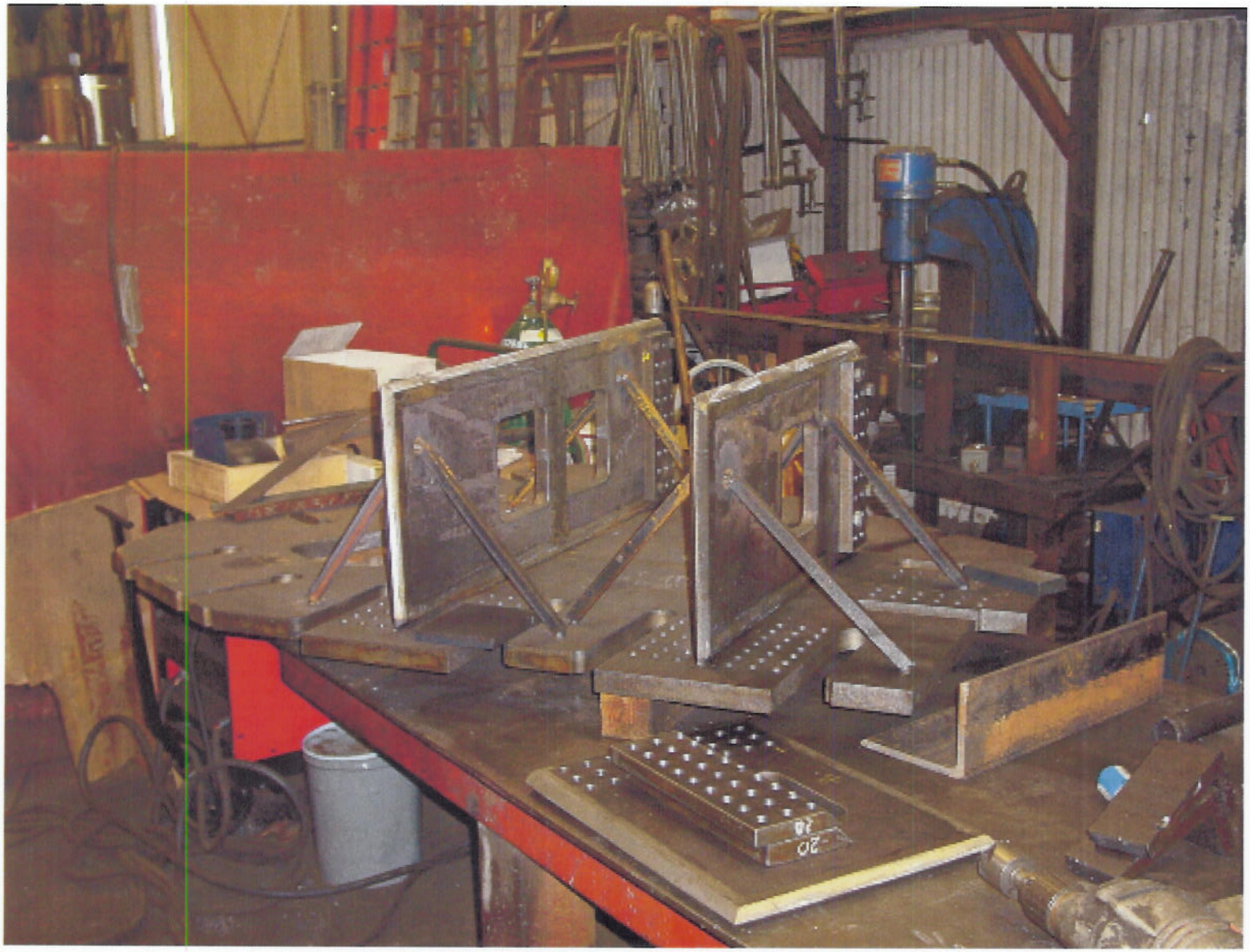
SFOBB tower shear-link

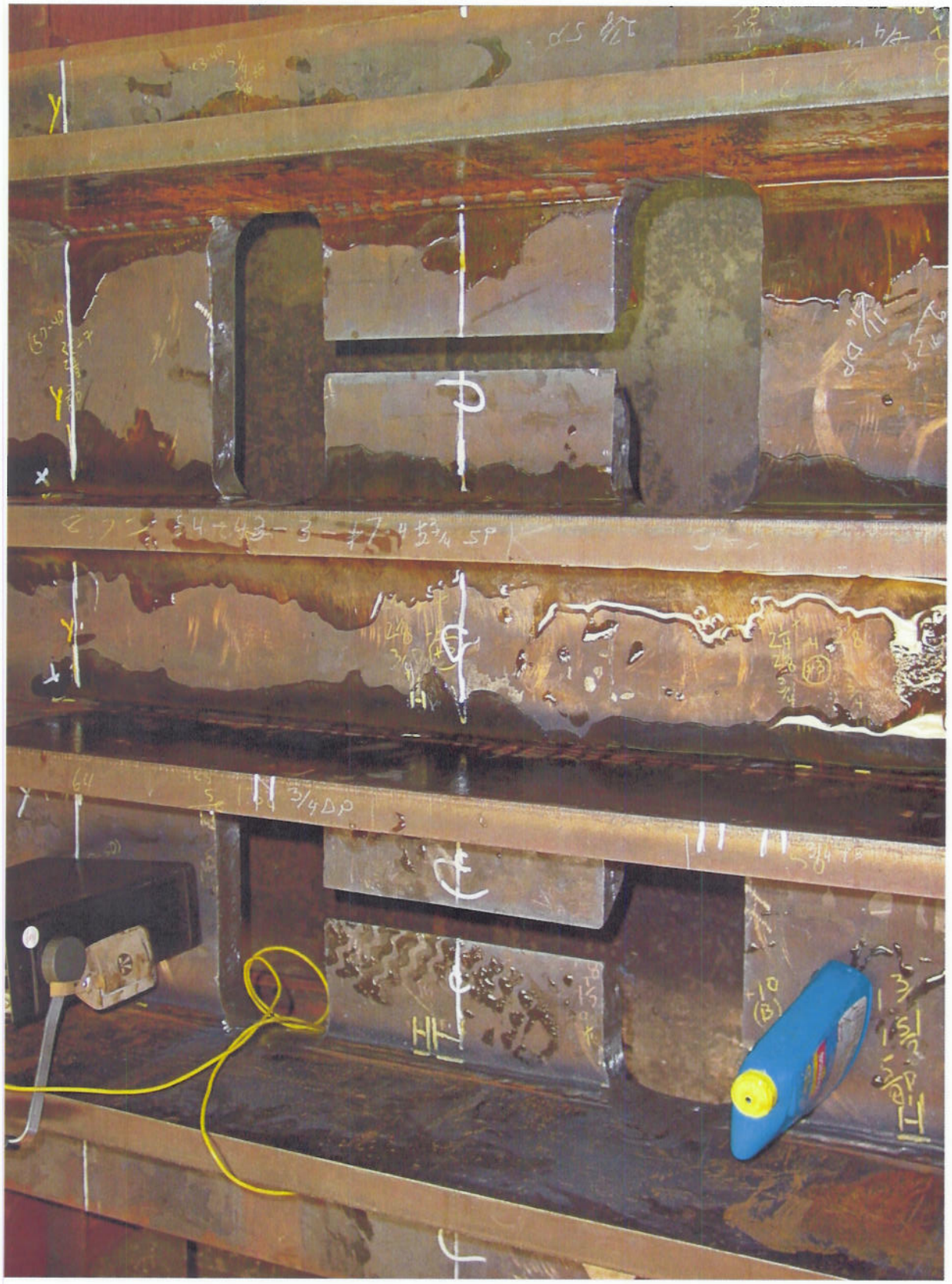


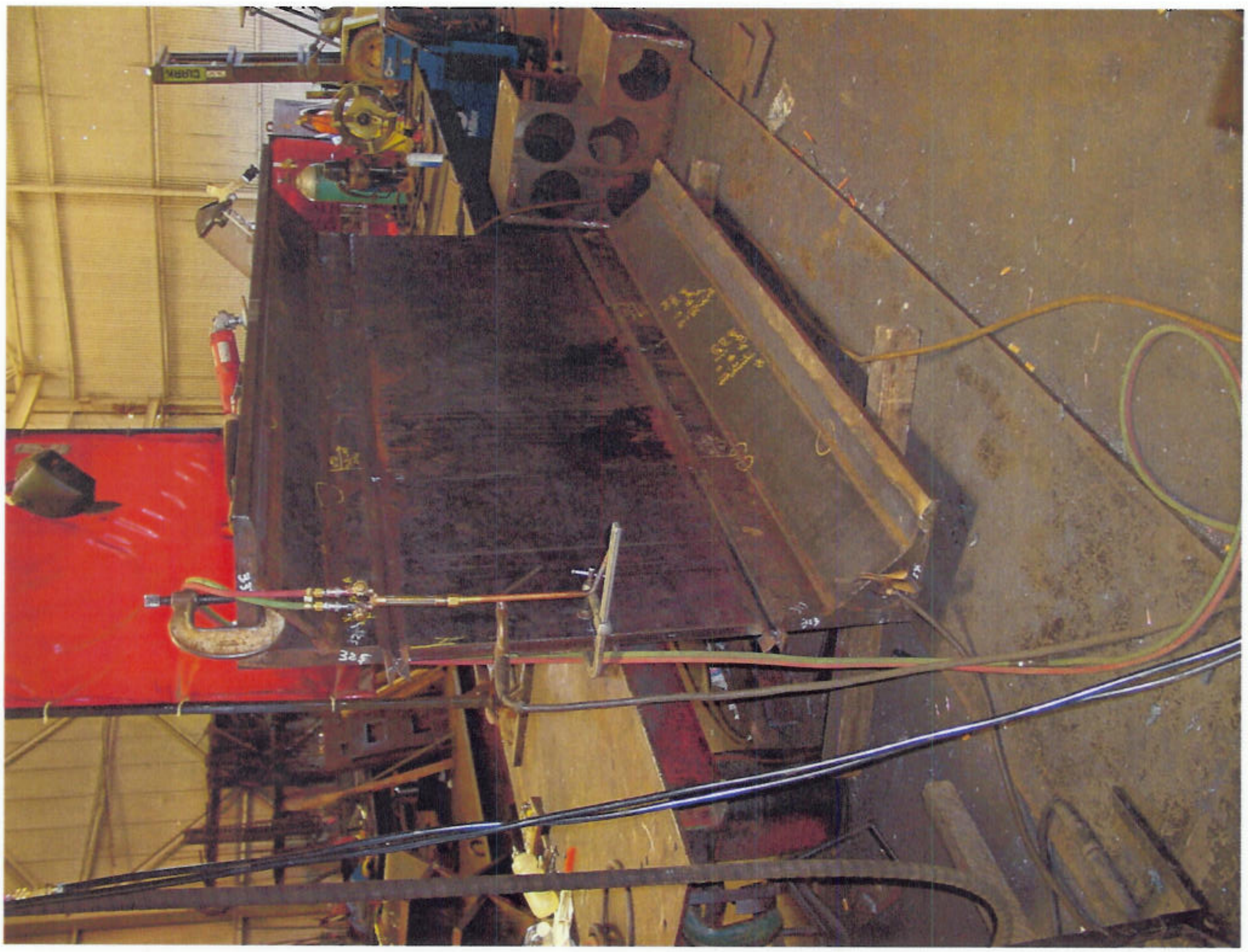
SFOBB tower-section construction sequence model

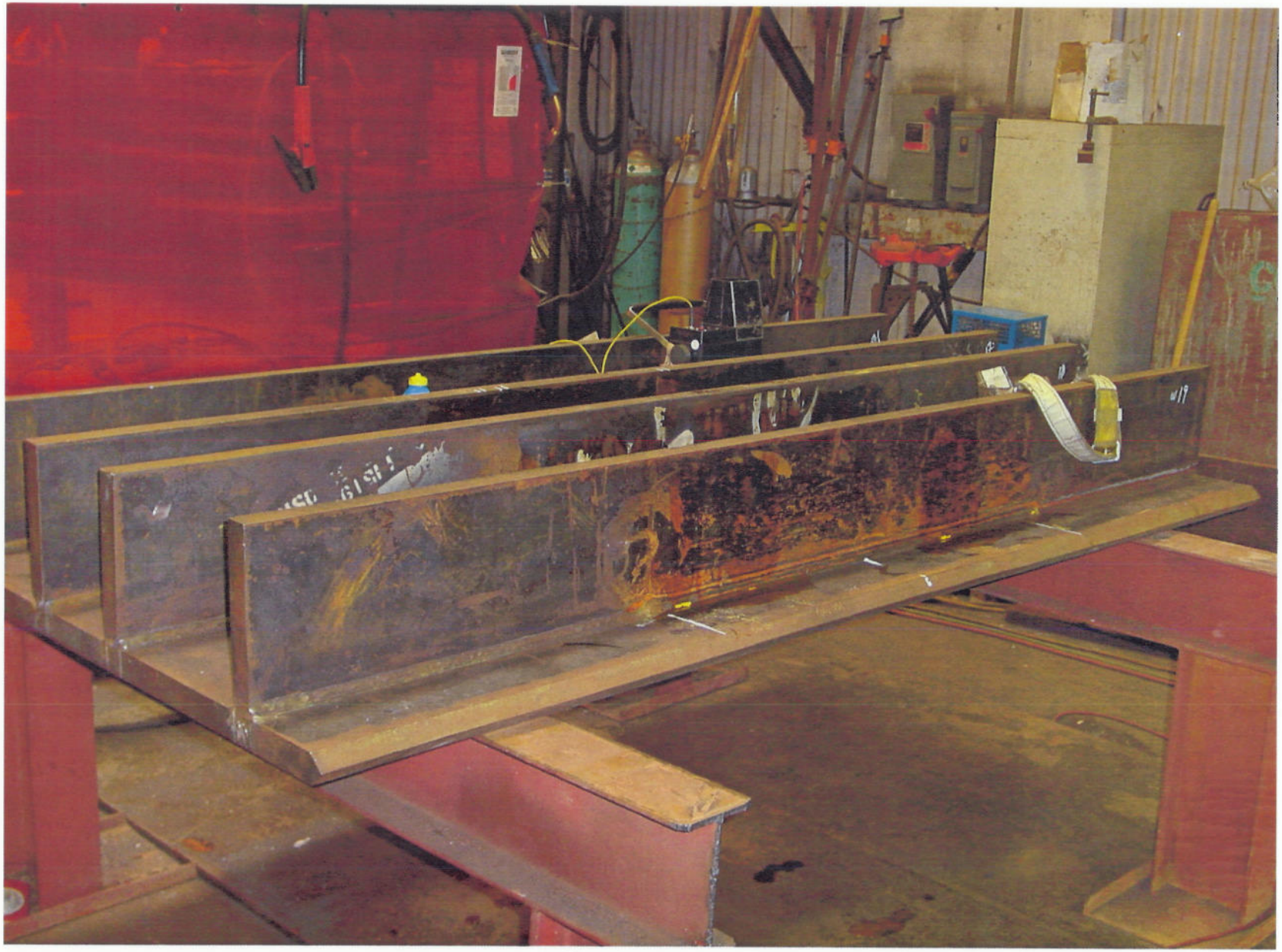


Experts at Work.jpg







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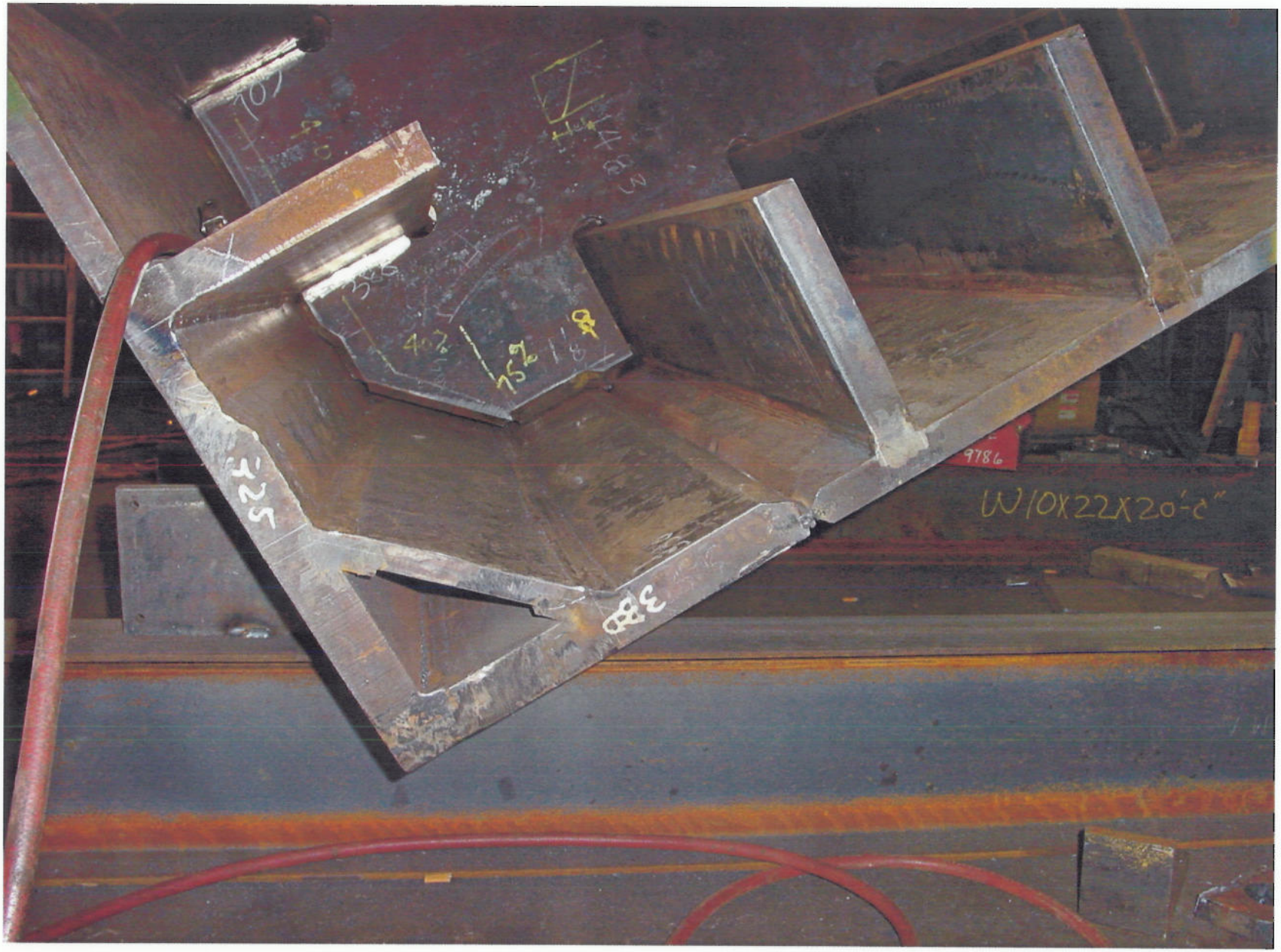
W10X22X20'-2"

D12 PLT-1
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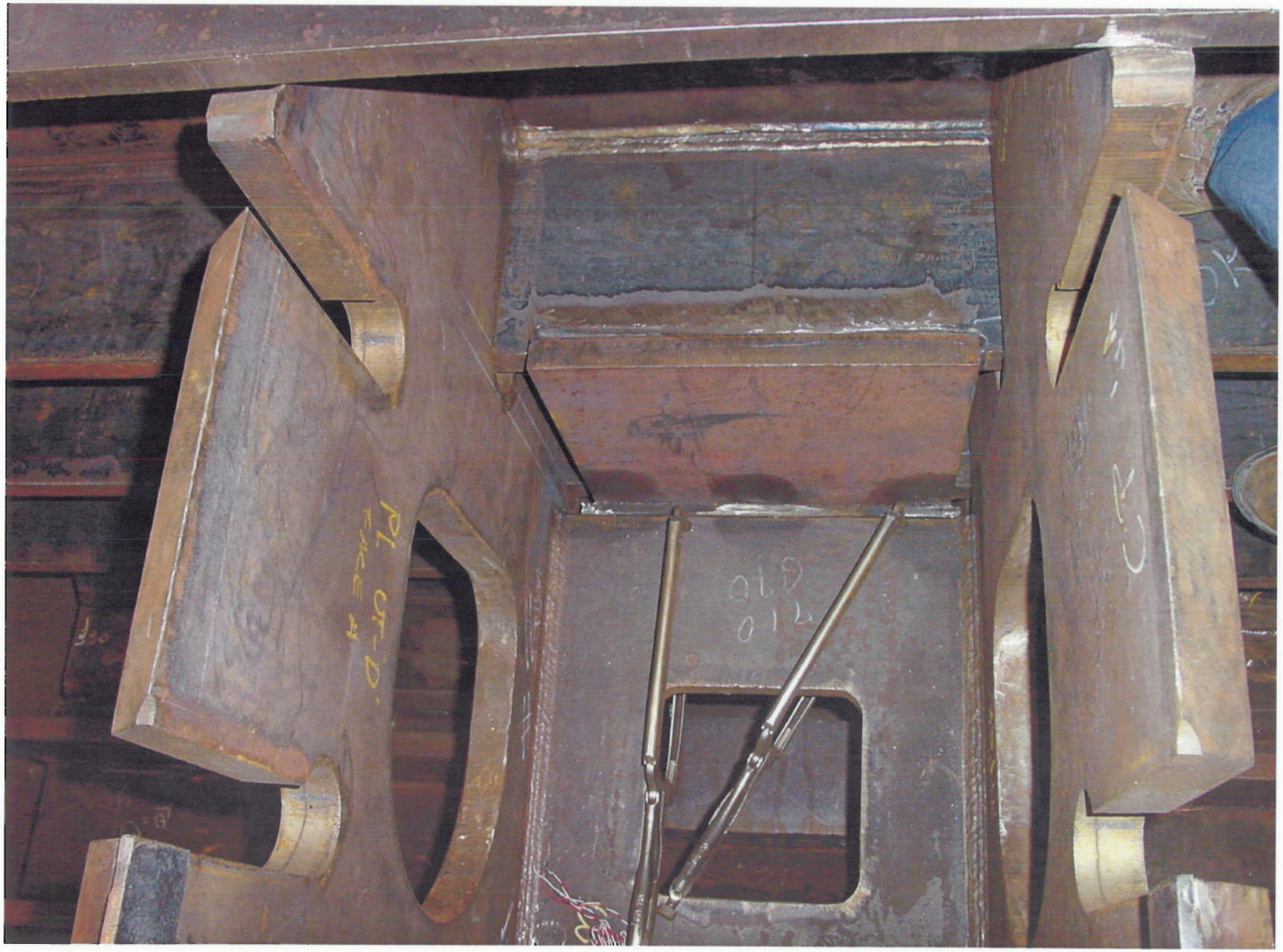
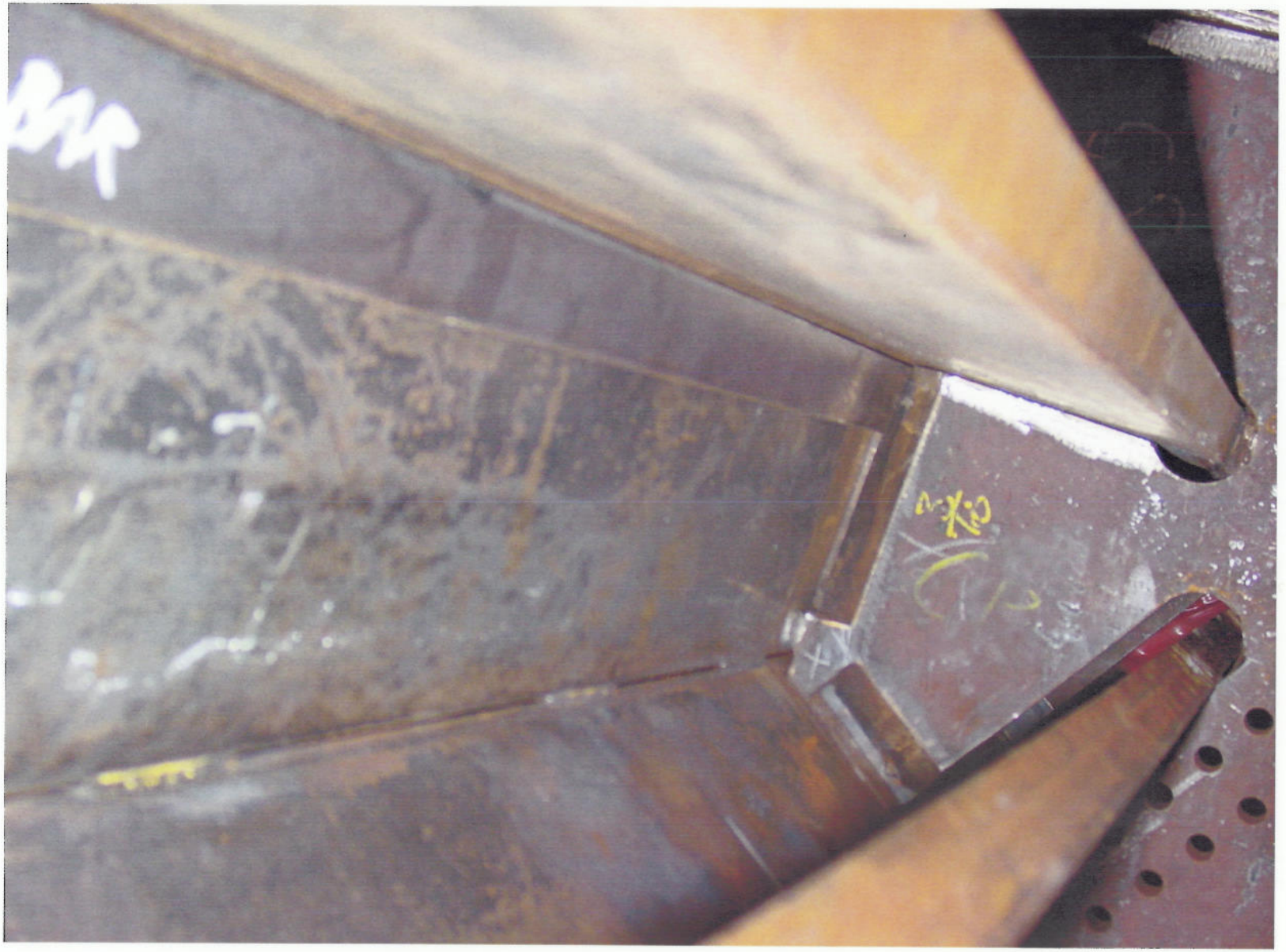
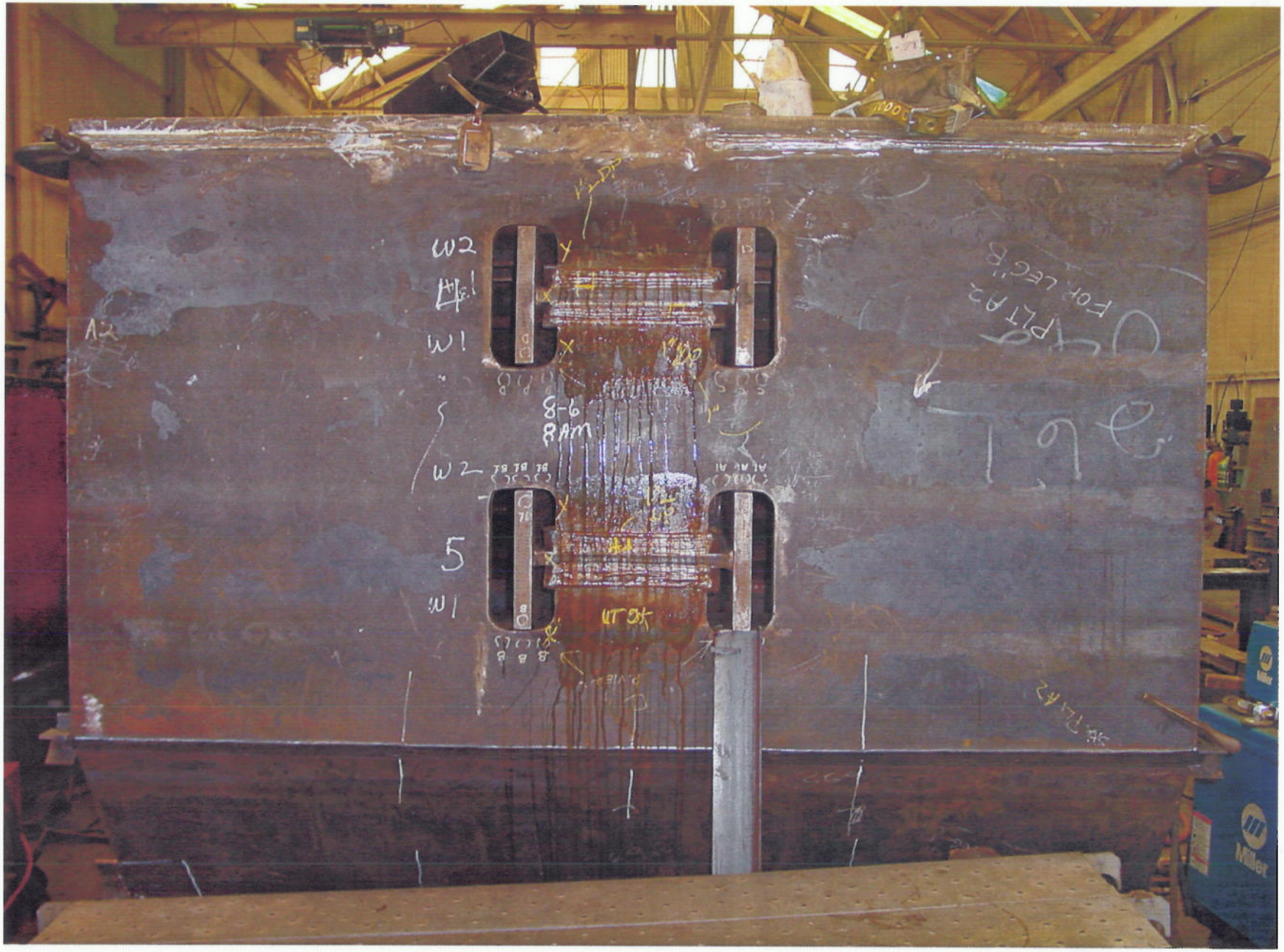

PL GT-D
FACE 4

45°
2 PLT 1




W2
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5
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UT OK
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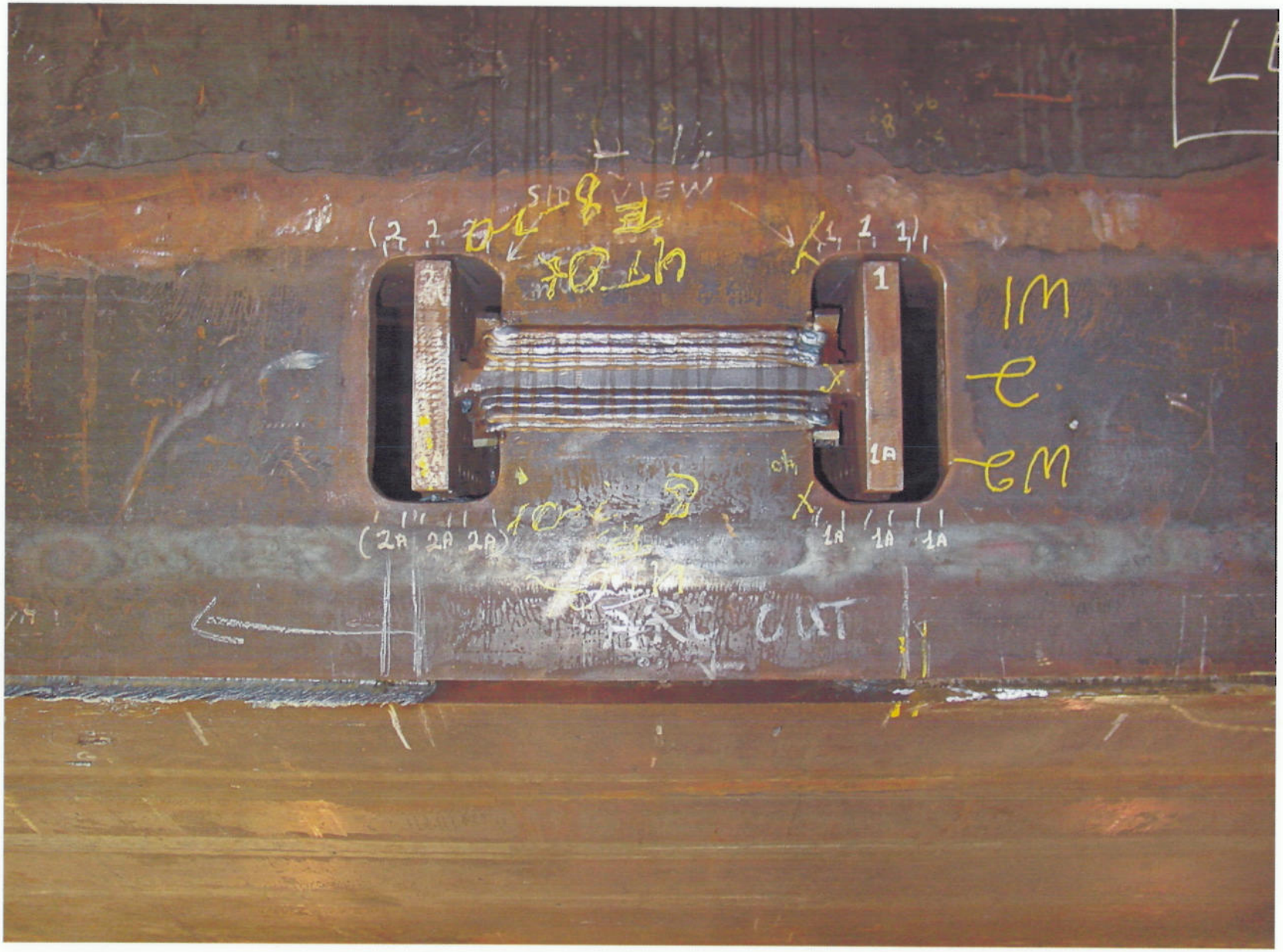
SIDE VIEW
1
1A
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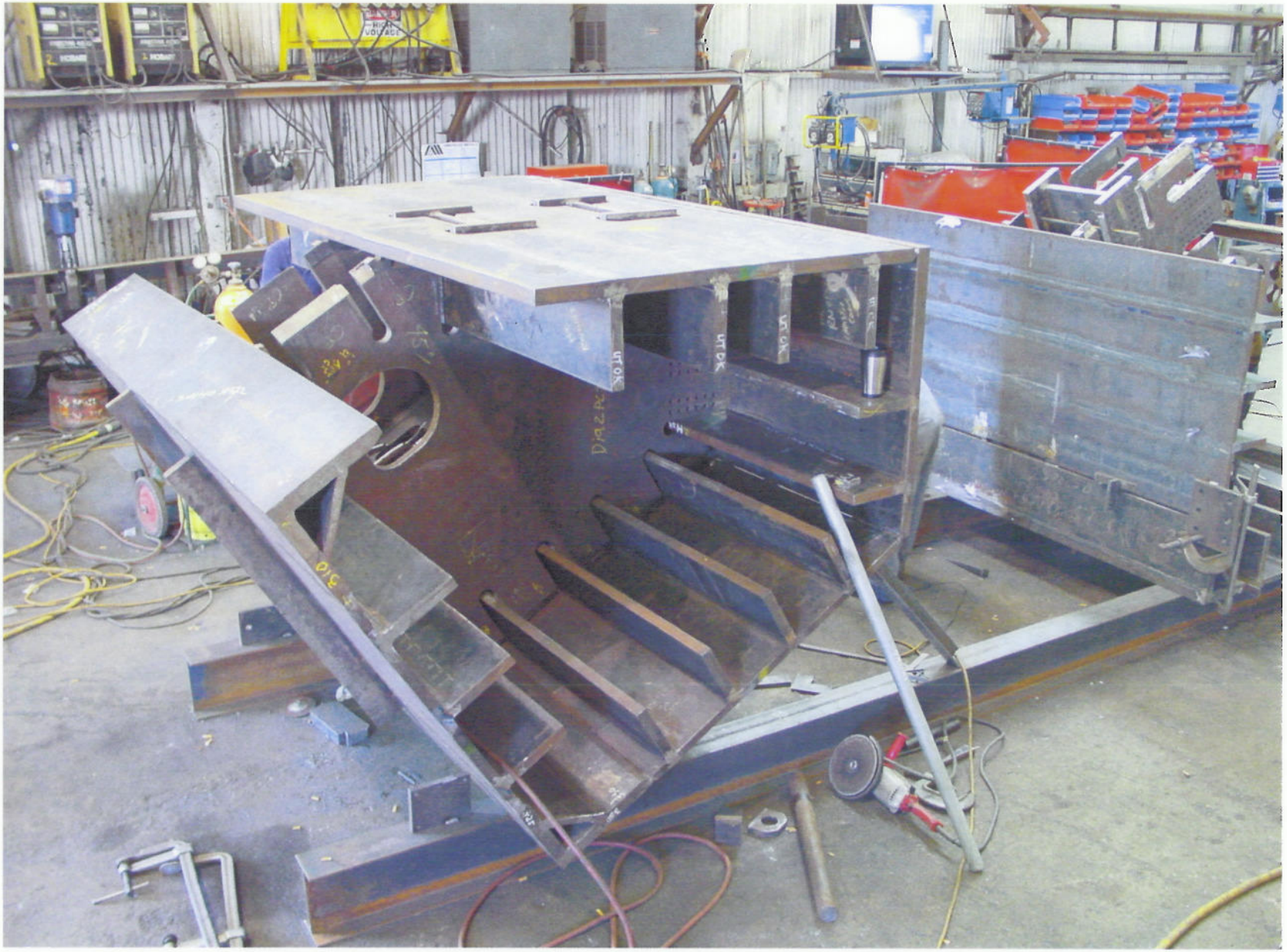
1A 1A 1A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LEGA "A"
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1757

SFOBB half-size tower-section and tower-link test rig at UNR